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An investigation of the relationship between percentage area coverage and ink film trapping

Daniel Garcia

An Investigation of the Relationship Between Percentage Area Coverage and Ink Film Trapping

by

Daniel Garcia

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Thesis Advisor: Professor Miles Southworth
Research Advisor: Professor Eric Sanderson
Coordinator: Professor Marie Freckelton

School of Printing Management and Sciences
Rochester Institute of Technology
Rochester, New York

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Master's Thesis

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Daniel Garcia

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Thesis Committee:

____
Thesis Advisor

____
Graduate Program Coordinator

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Director or Designate

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Calle 8. edif. Grapho-Formas. La Urbina.
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Abstract

An investigation of the relationship between percentage underneath area coverage and ink film trapping is presented. It is common knowledge that an ink generally adheres better to the paper than to a wet ink. This is known as undertrapping. To avoid this problem, printers set a limit for the total area coverage to be printed on the press sheet. The problem is that no formal study has been done to find the optimum point at which the limit should be set.

The investigation addresses the issue of total area coverage from a trapping point of view. This presents the behavior of ink trapping relative to different combinations of underneath area coverage. A test target with area coverage from 15% to 300% was printed underneath a solid. Ink trapping of the solid over the different combinations of underneath area coverage was determined densitometrically. A plot of the relationship between ink trapping and underneath area coverage demonstrates that there is an inverse and linear relationship between the two variables.

Introduction

The study of ink trapping is concerned with the ability of an ink to transfer to the surface onto which it is being printed. This surface can be the substrate, usually paper, another ink, or a combination of both. Percentage ink trapping is defined as ". . . how well a printed ink film covers a previously printed ink film relative to its coverage of an unprinted substrate."[1] To describe the ability of an ink to adhere to an already printed ink in relation to how it adheres to unprinted paper, we make a comparison of the amount of ink transferred to the ink film relative to the amount transferred to the paper. The comparison is expressed as a percentage.[2]

When the same amount of ink transfers to the printed ink as to the unprinted substrate, it is referred to as perfect or 100% trapping. Two other situations may occur. Overtrapping refers to the case in which more ink transfers to the printed ink than to the unprinted paper. When the amount of ink that transfers to the printed ink is less than the amount that transfers to the paper, we talk about undertrapping.

Ink trapping is an important factor in the assurance of good and consistent color reproductions. Ink trapping has an effect on the gray balance and color correction requirements. If ink trapping values are different than the values considered during the color separation stage, accurate color will be more difficult to achieve. Variation of ink trapping results in variation in color. The reason is that the color produced by two inks is the result of the relative amount of inks combined. This amount changes every time ink trapping changes. Variations of ink trapping of the last down ink will translate, in the case of undertrapping, into a color shift towards the color of the underneath ink layer. In the case of overtrapping the color shift will be towards the color of the last down ink.

One of the problems that printers have to deal with when attempting good color reproductions is that the density range of the original is greater than the density range that the printing process is capable to produce. The density range of the original has to be compressed to make it fit the density range of the printing process. Some information and detail is lost in the process. Part of the problem is because of the relatively low maximum density achievable by the printing process. The darker the shadow, the higher the maximum density achievable by a reproduction process.

Deep dark shadows are a desirable characteristic in color reproductions because they give a greater density range in which to fit the original's density range. In this way, less information and detail is lost in the tone reproduction process and a more accurate color reproduction obtained. Darker shadows can be achieved by printing a certain proportion of process inks along with black in these areas. This will help the shadow areas reach a higher density.

However, there are some problems that might occur when too much ink is printed. The three most important potential problems are contamination of one ink with others due to back trapping problems, drying problems, and inefficient trapping.

The general rule in the printing industry, and supported by the Specifications for Web Offset Publications[3], is that you should not print more that a total of 300% dot area coverage with only one unspecified ink as a solid. Nowadays, with the objective of obtaining the benefits of a higher shadow density, there are many printers that are pushing that recommended limit and are printing more than 300% maximum dot area coverage. There is no formal report on the results they are obtaining with this practice.

The purpose of the study is to investigate the relationship between underneath dot area coverage and ink trapping of the last down ink for SWOP printing conditions. We are interested in how different percentage dot area coverage underneath a solid printed ink affect the trapping values of that solid. We expect that the percentage of ink trapping of the solid will decrease as the percentage dot area coverage of the underneath inks increases. This is because in most of the cases "ink adheres more readily to paper than it does to a wet ink film."[4] Therefore the more area coverage underneath a solid ink the less the ink trapping values that solid will have.

If we were to plot the relationship between the percentage underneath dot area coverage and ink trapping, we anticipate that it would be an inverse one. What we don't know is the shape that the curve would have. It is important to study the shape of the curve that represents the relationship between dot area coverage and ink trapping because it will tell us the behavior of ink trapping for different values of percentage area coverage. This information can be used to determine the maximum printable dot area coverage that corresponds to the printer's standard trapping values. The objective of the investigation is to come up with a plot of the relationship between percentage dot area coverage and ink trapping. From that plot we will be able to make recommendations for maximum printable dot area coverage.

Endnotes for Chapter 1

[1] Field, G. "*Ink Trap Measurement.*" TAGA Proceedings 1985, p. 382

[2] Elyjiw, Z. "*More on ink trap.*" Graphic Arts Monthly. September 1981, p. 63

[3] *SWOP, Specifications for Web Offset Publications.* American Business Press and Magazine Publishers Assn. 1988.

[4] Southworth, M. and Southworth, D. *Quality and Productivity in the Graphic Arts.* Livonia, NY. Graphic Arts Publishing Co. 1989

Background Theory

Factors that affect ink trapping

In order to have consistent color through the press run, it is important to understand the influence of each of the individual factors on ink trapping. The factors that affect ink trapping are tack of the inks, ink film thickness, time between impressions, ink temperature, paper absorbency, ink water balance, and coverage.[5]

Tack of the inks. In order to have a good ink transfer situation, the tack of the second down ink should be lower than the tack of the first down ink. In the situation in which the tack of the second down ink is higher than the tack of the first down ink, a problem called back trapping may occur. In this case, some of the first down ink may be pulled off the paper and go to the ink fountain of the second down ink, contaminating it. In the case of multicolor printing, the tack of the inks should decrease from the first to the last unit.

Ink film thickness. Undertrapping is likely to happen if the ink film thickness of the second down ink is substantially smaller than the ink film thickness of the first down ink. The force required to split an ink film is inversely proportional to the cube of its ink film thickness[6]. The thicker it is the easier it is to split it and therefore the easier the transfer. It is recommended that in the case of multicolor printing the ink film thickness should be the same or increase slightly from the first unit to the last.

Time between impressions. The tack of a printed ink increases during setting. The longer the setting time the more the ink will set, which means that the tack will also increase. If more time is allowed between the first and the second impression, the first down ink will be tackier at the time it receives the second down ink. This tack increase facilitates the trapping of the second down ink. If the time between impressions is too long as in the case of multicolor jobs on a single color press, dry trapping problems may occur. The most common is that additives in the first ink may migrate to the surface of the ink film and act as a barrier to the printing of the other inks.

Ink temperature. An increase in the temperature of the ink will cause its tack to decrease and therefore could affect its trapping performance. The temperature of the inks should be maintained the same all through the press run.

Paper absorbency. The more absorbent the substrate, the quicker the penetration of the ink vehicle into the substrate. This action causes an increase in the tack of the printed ink, which facilitates the trapping of the next ink.

Ink water balance. There is in the lithographic process a balance between ink and water that should be maintained. Changes in that balance have an effect on the tack of the inks and therefore on ink trapping. If too much water is fed, the ink tack will tend to decrease. If not enough water is fed, the ink tack will tend to increase. This is because "the water take-up normally reduces the viscosity of the ink and lowers the tack."[7] Maintaining the proper ink water balance for every printing unit is an important factor in lithography and has an effect on a lot of different variables, ink tack being one of them.

Area coverage. A difference in area coverage of the plate will usually cause a change in the tack of the ink. A plate with a light image area will cause the ink to stay longer in the ink fountain because not too much replenishment is needed. This will cause the solvent portion of the ink to evaporate from the ink trein. The tack of the ink will be higher when it reaches the plate. Following this argument, a light covered area will tend to trap better than a heavy covered area.[8] The effect of area coverage over ink trapping is not known for sure, and it remains an area that needs further investigation and research.

As we can see there are a lot of factors that can affect ink trapping. In a production situation these factors have to be controlled in order to maintain ink trapping within accepted limits. Monitoring ink trapping during a press run is very important, but in order to do that we have to first know how to measure ink trapping.

Measurement of ink trapping.

There are a number of different ways to measure ink trapping. Some of them are suitable for production situation, others only for the laboratory. In this section there is a recompilation of the most important methods to measure ink trapping.

Gravimetric method. This method attempts to measure the actual quantity of ink that is transferred to a previously printed substrate relative to an unprinted one. The amount of ink transferred is measured in terms of ink film thickness or the weight of ink per unit area. The image carrier or plate is inked and weighed before and after the impression. By subtracting these two values the amount of ink transferred can be calculated. The amount of ink transferred to the preprinted substrate is divided by the amount of ink transferred to the unprinted paper and the result is multiplied by 100. The formula expresses this relationship:

$$\% \text{ GMT} = (\text{IFT } 2/\text{IFT } 1) \times 100 \%$$

where:

% GMT = Percent of gravimetric trapping.

IFT 2 = amount of second down ink transferred to the already printed substrate.

IFT 1 = amount of second down ink transferred to the unprinted paper.

An IGT printability tester with two printing discs or a two color proofing press can be used for making the experiment for measuring percent trapping using the gravimetric method. When using the IGT printability tester, two printing discs are used. Each of them is inked with a different ink. The first disc transfer the first down color and the other disc the second down color. A strip of the substrate being tested is printed by both discs. The disc that prints the second down ink is weighed before and after printing. Ink trapping is then calculated following the method already described.[9]

X-Ray Fluorescence Spectroscopy Method. The objective of this method is to actually measure the ink film thickness rather than to estimate it. Ink trapping is calculated from the measurement of the ink film thickness of the ink printed over the paper and over other ink.

The method relies on the X-ray quanta that is emitted from an atom when an electron from an inner shell is ejected and the higher level electrons readjust to fill the deficiency and render the natural state of the atom. The nature of the wavelengths of these X-ray quanta is a characteristic of each element. The ejection of an inner electron can be accomplished when an X-ray beam of enough energy is incident over the element under study.[10]

The intensity of the radiation emitted by a sample containing a specific element is related to the concentration of the element on the sample. In the case of thin films this relationship is linear. This means that the higher the concentration of the particular element on the sample, the stronger the X-ray emission will be. In order to measure ink film thickness by this method, there must be a particular element in every ink that is present neither in the other inks nor in the paper. This particular element can be one introduced in the inks or can be the natural occurring metals on the pigments of the inks.

Gravimetric measurements of different ink film thicknesses of the inks used to print are done. Then the concentration of the metal specific to each ink is measured and a correlation or look up table is built to come up with the relationship between ink film thickness and concentration of the metals in the samples. After the samples are printed, the measurements of the thickness of the ink film printed over paper and printed over other inks are collected. The following formula is applied:

% Trap = (IFT 2/IFT 1) x 100 %

where:

% Trap = Percent trapping.

IFT 2 = Ink film thickness printed over other inks.

IFT 1 = Ink film thickness printed over the paper.

Densitometric method. The densitometric method uses densitometry as the means to estimate the ink film thickness. It has the advantage that it can be used in a real production situation with a densitometer. The densitometric method is based on the existing relationship between density and ink film thickness. The thicker the ink film the greater the density. But after a certain point this relationship is not a linear one. There is a point when an increase in the ink film thickness will not translate in an increase in density.

If we were to measure the density of an overprint of two inks we would expect its density to be the sum of the densities of the individual inks. In other words, "the density of a combination of inks, as measured through a given filter, is equal to the sum of the densities of the individual inks measured through the same filter."[11] This is known as the additivity rule. When it does not hold, as in the practice, we talk about additivity failure. In fact this rule only holds for transmission densitometry with non-scattering samples and not for reflection densitometry.

Yule and Clapper[12] investigated the factors that cause additivity failure. They call them causes of nonadditivity. These factors are as follows: First surface reflections, multiple internal reflections, opacity, ink trapping, back transfer effects, spectral characteristics, halftone structure, and light scatter in the paper.

Measuring Ink Trapping Using Densitometry.

There are three proposed equations for measuring ink trapping using densitometry. They are known as the Preucil, the Childers, and the Brunner ink trapping equations.

Preucil equation. Preucil based his formula in the definition of ink trapping. He was interested in measuring the ink film thickness of an ink printed over another ink as compared with printing the same ink over unprinted paper. The formula is as follows:

$$\% \text{ Ink Trap} = (Dop - D1) / D2 \times 100 \%$$

Where:

Dop = Density of the overprint.

D1 = Density of the first down ink.

D2 = Density of the second down ink.

All the densities are measured through the color filter complementary to the second down ink. Preucil used density as an approximation of ink film thickness. He was aware that the other additivity failure factors were preventing him from obtaining the real ink trapping values. This is why he called "apparent trapping" to be the result of his equation. He believed that measuring the real ink trapping was not as important as measuring changes in it. Preucil's formula is the most used ink trapping formula used today.

Childers equation. Childers criticized Preucil's equation because the numbers represented ratios of logarithms. He proposed that the ink trapping calculation must be based on antilogarithm instead. His formula is as follows:

Percent Trap = 10^ (Dop - D1 - D2) x 100 %

Where:

Dop = Density of the overprint.

D1 = Density of the first down ink.

D2 = Density of the second down ink.

All the densities are measured through the color filter complementary to the second down ink. Elyjiw[13] criticized Childer's equation because it calculated ink trapping values that were further away from the actual values than the results calculated by Preucil's equation. It seems that what Childers didn't understand was that the use of densities was just a way to estimate ink film thickness. Once this is understood, densities are no longer logarithmic calculations but physical ink film thickness.

Brunner equation. In 1984 Felix Brunner proposed a new ink trap formula as part of his System Brunner to keep track of several print characteristics. His argument is that the new formula allows trapping to be expressed as effective relative absorptance. The equation is as follows:

Percentage trap = [1 - 10 ^ (-Dop) / 1 - 10 ^ -(D2 + D1)]

Where:

Dop = Density of the overprint.

D1 = Density of the first down ink.

D2 = Density of the second down ink.

All the densities are measured through the color filter complementary to the second down ink. "The similarity between this and the Murray-Davies equation allows us to interpret percentage ink trapping as an effective relative absorptance of the two color patch."[14] In this way, a two color overprint of yellow over cyan with lets say 90% undertrapping, produces the same green overprint that would be produced by a 90% dot of a green ink having a solid ink density that is the sum of the individual solid ink densities.

Field (1985) and Hamilton (1985) did an evaluation of these ink trapping formulas. They inputted different theoretical and practical values in the equations and analyzed the results given by them. Hamilton observed that in the case of perfect trapping, that is, when the amount of ink transferred on top of another ink is the same as the amount of ink transferred to the unprinted paper, all three equations give a value of 100%. On the other hand, in a case where no ink transfers on top of the already printed ink, only Preucil's equation give a value of 0%.

Field indicates that Preucil's equation is the only one to respond in a linear manner to the changes in ink film thickness. Although the Childers and Brunner equations predict the direction of the change of percent ink trapping, they are not reliable for calculating the magnitude of the change. The reason for this is that these equations don't maintain a linear relationship with the changes in ink film thickness.

As part of his conclusions, Field adds that for control purposes on the press, actual trapping values are not needed. It seems that Preucil's formula predicts ink trapping changes with enough accuracy to be used for process control. This equation will give better results than the equations proposed by Brunner and Childers.

Endnotes for Chapter 2

[5] Field, G. *Color and its reproduction.* Pittsburgh, PA. Graphic Arts Technical Foundation. 1988.

[6] Eldred, R. and Scarlett, T. *What the printer should know about ink.* Pittsburgh, PA. Graphic Arts Technical Foundation. 1990.

[7] Field, G. *Color and its reproduction.* Pittsburgh, PA. Graphic Arts Technical Foundation. 1988.

[8] Field, G. *Color and its reproduction.* Pittsburgh, PA. Graphic Arts Technical Foundation. 1988.

[9] Lawphongpanish, K. *Comparison of densitometric measurement with gravimetric measurement of wet on wet ink trapping.* M.S. Thesis, RIT. 1981.

[10] Ghany, A. *"Wet on wet printing: an analysis of trapping problems."* Professional Printer. October 1981, p. 10

[11] Field, G. *"Ink Trap Measurement."* TAGA Proceedings 1985, p. 382

[12] Yule, J. and Clapper, F. *"Additivity of ink densities in multicolor halftone printing."* TAGA Proceedings 1956, p. 156

[13] Elyjiw, Z. *"More on ink trap."* Graphic Arts Monthly. September 1981, p. 63

[14] Hamilton, J. *"Ink Trap: The Moving Target."* TAGA Proceedings 1985, p. 397

Methodology

The objective of this investigation was to characterize the behavior of ink trapping when printed on different levels of underneath percentage dot area coverage. The study investigates the relationship between ink trapping and underneath percentage dot area coverage. The results of the research gave the ink film trapping values of a solid ink for the different combinations of underneath area coverage. The investigation required the running of an experiment. It consisted of the printing of a customized color target from which the required data was collected.

The printing of the color target followed the black, cyan, magenta, and yellow printing order. This is the most common and recommended printing order. This order "makes the reproduction of accurate color easier to achieve."[15] The reason is that the KCMY printing order tends to minimize the color variation caused by undertrapping as it takes into account the hue errors already existing in the inks and the need to reproduce good red, blue, and green colors.

Ink trapping of the overprint yellow ink was measured densitometrically and calculated using Preucil's formula. For the use of Preucil's or any other densitometric method in this investigation a consideration had to be made. Printing with black ink would make the densitometric evaluation of ink trapping difficult and misleading. However, the problem was minimized by printing with another process ink in the black printing unit. The alternative ink could be cyan or magenta. In this way the densitometer was better able to distinguish the differences in densities and the measurements had more significance. The ink chosen to print instead of black was cyan. This is because of the low amount of yellow contamination that cyan inks have in average. The result is that cyan was printed in the first two units of the press, magenta in the third, and yellow in the forth. The double cyan plus the magenta allowed us to produce a maximum of 300% area coverage underneath the yellow.

The definition of trapping tells us that in order to calculate it we have to observe how an ink transfers to an already printed surface relative to how it transfers to the unprinted substrate. For that reason, in our target we needed the overprinting or last down solid printed over the paper and over each of the different underneath percentage dot area coverage values.

A diagram of the color target is presented in Figure 1. A sample of the actual printed target is included in Figure 2. The color target is divided in two parts. The left part represents the different combinations of underneath dot area coverage. They range from 0% to 300% in 15% increments. Each of the steps is formed by equal participation of the three first down inks, that is cyan 1, cyan 2, and magenta. The right part of the target is a repetition of the left one with 100% yellow printed over all the different cyan 1, cyan 2, and magenta combinations.

The target was printed on R.I.T.'s Harris M-1000B according to SWOP specifications. Normal production conditions were simulated. This means that the press crew controlled the different factors that affect print quality and performance as if they were printing an average subject. The press crew tried to maintain all the printing characteristics constant. This gave more significance and validity to the results. With consistent printing all color variations that appeared in the test target were the result of the varying amounts of ink underneath the solid yellow. This made the relationship of ink trapping to percentage underneath area coverage more valid.

The target was printed on coated paper with SWOP inks. At the time of printing the target, the press crew did the make ready and achieved the color OK. The press ran for ten minutes after the color OK and ten consecutive signatures were gathered. Ink trapping was measured from the ten samples. Taking ten samples minimized any measurement error and sheet to sheet variation. The average of the ink trapping values was calculated and was used as the final ink trapping values in the study.

Statistical analysis was used to estimate the existing relationship between the different combinations of underneath dot area coverage and their corresponding ink trapping values. A graph of the relationship was plotted. Figure 3 represents a sample of the axes in which the relationship was plotted. The plot was used to demonstrate the behavior of ink trapping and to make recommendations for total dot area coverage.

Materials and equipment used

This section contains all the relevant information referent to the materials and equipment used in this investigation. It also describes the conditions under which the color target was printed and measured.

Press manufacturer: Harris M-1000B

Blanket manufacturer: Reeves Marathon. 3 ply compressible.

Plate manufacturer: 3M GMX

Fountain Solution manufacturer: Rosos KSP500 AS m-4.

Dampening system: Harris Duotrol

Ink manufacturer: Flint

Paper manufacturer: S. D. Warren

Dryer manufacturer: TEC 2 zone high velocity.

Densitometer: X-Rite 418

Printing conditions:

Density aim points: Cyan 1: 1.20

Cyan 2: 1.20

Magenta: 1.35

Yellow: .95

Actual densities obtained during pressrun:

Cyan 1: 1.20 ± 0.04

Cyan 2: 1.20 ± 0.04

Magenta: 1.35 ± 0.04

Yellow: .95 ± 0.04

Press Speed: 1.200 feet per minute.

Paper used: S. D. Warren Somerset web gloss 45lb. 33qo40411D.

Inks used: Unit 1: Arroweb process blue F4 B074 T10604

Unit 2: Arroweb process blue F4 B074 T10604

Unit 3: Arroweb process red F4 R091 T10605

Unit 4: Arroweb process yellow F2 y761 T8684

Fountain Solution conductivity: 2175

Tack of the inks: Unit 1: 13.6

Unit 2: 13.6

Unit 3: 10.8

Unit 4: 9

Dryer temperature: 250° at the exit.

Figure 1

Diagram of the color target

100% yellow	100% yellow	100% yellow	100% yellow
5% cyan 1 5% cyan 2 5% magenta Total = 15%	55% cyan 1 55% cyan 2 55% magenta Total = 165%	5% cyan 1 5% cyan 2 5% magenta Under 100% yellow	55% cyan 1 55% cyan 2 55% magenta Under 100% yellow
10% cyan 1 10% cyan 2 10% magenta Total = 30%	60% cyan 1 60% cyan 2 60% magenta Total = 180%	10% cyan 1 10% cyan 2 10% magenta Under 100% yellow	60% cyan 1 60% cyan 2 60% magenta Under 100% yellow
15% cyan 1 15% cyan 2 15% magenta Total = 45%	65% cyan 1 65% cyan 2 65% magenta Total = 195%	15% cyan 1 15% cyan 2 15% magenta Under 100% yellow	65% cyan 1 65% cyan 2 65% magenta Under 100% yellow
20% cyan 1 20% cyan 2 20% magenta Total = 60%	70% cyan 1 70% cyan 2 70% magenta Total = 210%	20% cyan 1 20% cyan 2 20% magenta Under 100% yellow	70% cyan 1 70% cyan 2 70% magenta Under 100% yellow
25% cyan 1 25% cyan 2 25% magenta Total = 75%	75% cyan 1 75% cyan 2 75% magenta Total = 225%	25% cyan 1 25% cyan 2 25% magenta Under 100% yellow	75% cyan 1 75% cyan 2 75% magenta Under 100% yellow
30% cyan 1 30% cyan 2 30% magenta Total = 90%	80% cyan 1 80% cyan 2 80% magenta Total = 240%	30% cyan 1 30% cyan 2 30% magenta Under 100% yellow	80% cyan 1 80% cyan 2 80% magenta Under 100% yellow
35% cyan 1 35% cyan 2 35% magenta Total = 105%	85% cyan 1 85% cyan 2 85% magenta Total = 255%	35% cyan 1 35% cyan 2 35% magenta Under 100% yellow	85% cyan 1 85% cyan 2 85% magenta Under 100% yellow
40% cyan 1 40% cyan 2 40% magenta Total = 120%	90% cyan 1 90% cyan 2 90% magenta Total = 270%	40% cyan 1 40% cyan 2 40% magenta Under 100% yellow	90% cyan 1 90% cyan 2 90% magenta Under 100% yellow
45% cyan 1 45% cyan 2 45% magenta Total = 135%	95% cyan 1 95% cyan 2 95% magenta Total = 285%	45% cyan 1 45% cyan 2 45% magenta Under 100% yellow	95% cyan 1 95% cyan 2 95% magenta Under 100% yellow
50% cyan 1 50% cyan 2 50% magenta Total = 150%	100% cyan 1 100% cyan 2 100% magenta Total = 300%	50% cyan 1 50% cyan 2 50% magenta Under 100% yellow	100% cyan 1 100% cyan 2 100% magenta Under 100% yellow

Figure 2

Sample of the printed color target

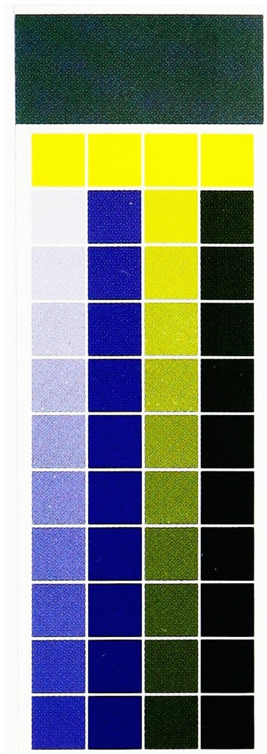
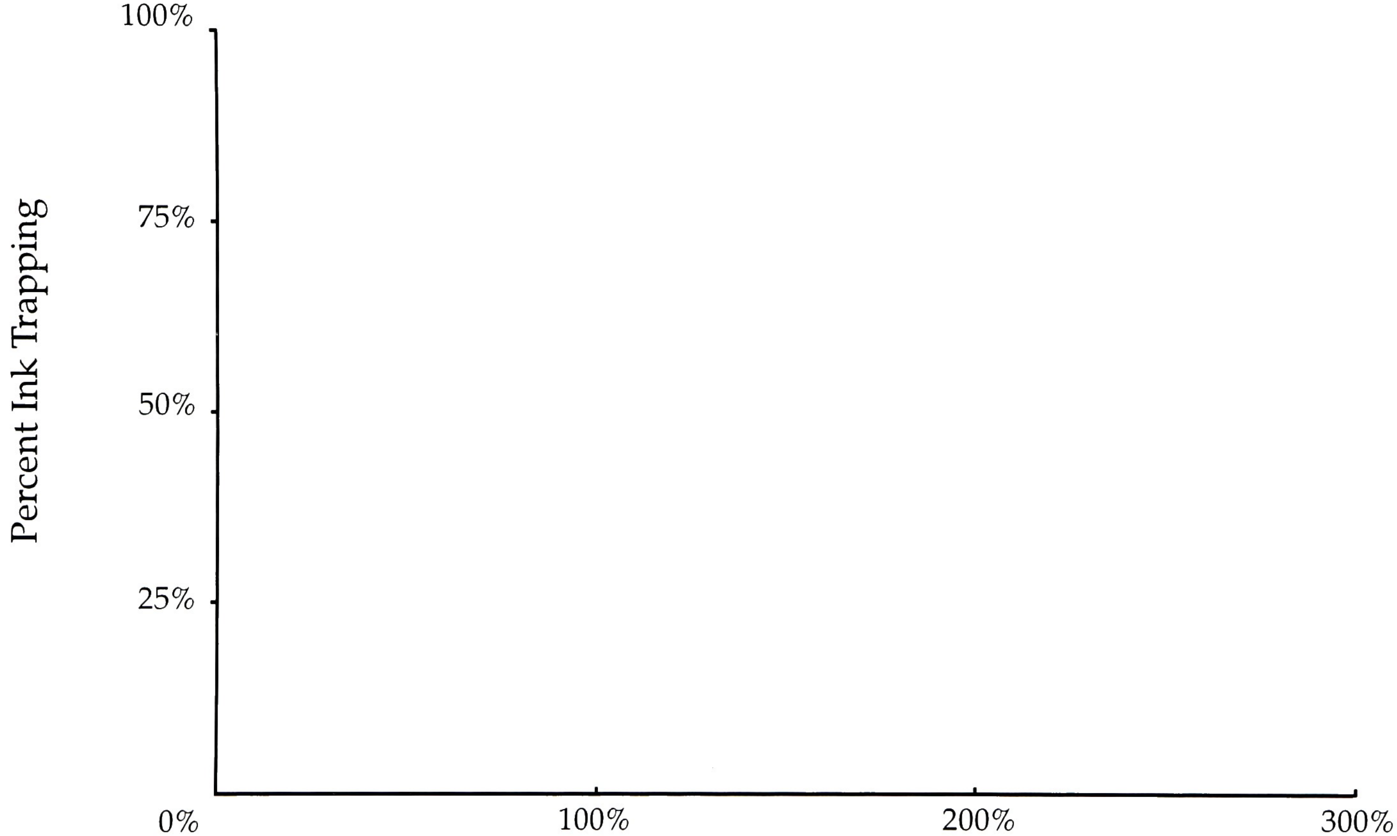


Figure 3

Sample of Final Plot Axes



Endnotes for Chapter 3

[15] Southworth, M. and Southworth, D. *Quality and Productivity in the Graphic Arts.* Livonia, NY. Graphic Arts Publishing Co. 1989.

Results

After the printing of the color target, densitometric measurements were taken from the individual patches in each of the ten successive samples to minimize measurement error. The density values obtained for each of the samples are presented in tables 1-1 to 1-10. The layout of these tables follows the same layout as the printed target. The numbers in the tables represent the blue filter density readings taken from each of the ten samples gathered for the experiment.

Using Preucil's equation, and based on the densitometric readings obtained, trapping for each of the samples was calculated. The percent trapping values that correspond to each underneath area coverage on the color target are presented in Table 2. Figure 4 is presented for a better visualization of the results. It was made based on the trapping values obtained for the different amounts of underneath area coverage for each of the sample.

The statistical averages of the trapping values of each underneath area coverage for the samples were then calculated. These averages are presented in Table 3, and the graphical plot of that data is contained in Figure 5. Table 3 and Figure 5 represent the relationship between percentage ink trapping and percent underneath area coverage at that particular press run under the printing conditions described in the methodology.

When analyzing the data we can see the same trend and curve shape in the graph of the relationship between the two variables for all of the individual samples since the sample to sample variation was minimum. The general trend and curve shape is shown again for the average trapping values.

The range of ink trapping values for the different underneath area coverage combinations varied from 104% to 72%. At 15% underneath area coverage, a situation of overtrapping occurred. This may have been caused by an increase in gloss due to the underneath inks. In average, 100% trapping happened at 30% underneath area coverage, a point at which the theory says that an undertrapping situation would have occurred.

The lowest ink trapping value for all of the samples was 70% at 300% underneath area coverage. The average was 72% ink trapping for 300% underneath area coverage. This means that we had 72% ink trapping when printing four wet solid inks, one on top of the other. It is interesting to compare this ink trapping value with the ink trapping values reported in the North American Commercial Print Survey in 1988[16]. The average values reported by that survey were 70.5% for the red overprint, 87.3% for the green overprint, and 72.3% for the blue overprint.

SWOP specifications recommend a maximum total area coverage of 300%. In our color target we got 80% ink trapping for the 200% area coverage underneath the solid yellow, which is a point of 300% total area coverage. For total area coverage values of less than 300% we obtained more than 80% ink trapping, and for total area coverage values of more than 300% we obtained less than 80% ink trapping. Based on these results we think that the SWOP specification for total area coverage is a valid one if the printer wants to have at least 80% ink trapping in the last ink down.

Another interesting finding from this research was the resulting slope and shape of the curve showing the relationship between ink trapping and percent underneath area coverage. The curve has a negative slope, which confirms the theory that the less the amount of ink underneath, the better that ink adheres to the substrate. We can see that there is a linear relationship between ink trapping and percent underneath area coverage. There is no critical point above which ink trapping values begin to fall drastically. Ink trapping values fall at almost a constant rate through the whole range of the different amounts of underneath area coverage.

Density values of the individual samples

Table 1-1

Db Undercolor		Db Overprint		
0,05	0,46	1,09	1,28	
0,09	0,48	1,11	1,30	
0,13	0,51	1,13	1,31	
0,17	0,55	1,18	1,33	
0,21	0,57	1,19	1,34	
0,26	0,60	1,21	1,35	
0,30	0,63	1,22	1,37	
0,35	0,66	1,26	1,38	
0,39	0,68	1,30	1,39	
0,45	0,69	1,33	1,40	
1,03	1,03	1,04	1,01	Db 100% Yellow

Table 1-2

Db Undercolor		Db Overprint		
0,05	0,46	1,08	1,28	
0,09	0,49	1,09	1,30	
0,13	0,51	1,11	1,31	
0,17	0,55	1,15	1,31	
0,21	0,57	1,17	1,32	
0,26	0,60	1,18	1,31	
0,30	0,62	1,21	1,33	
0,35	0,65	1,23	1,36	
0,39	0,66	1,27	1,37	
0,45	0,67	1,30	1,37	
1,01	1,01	1,03	1,00	Db 100% Yellow

Density values of the individual samples

Table 1-3

Db Undercolor		Db Overprint		
0,06	0,47	1,09	1,31	
0,09	0,50	1,12	1,31	
0,14	0,51	1,13	1,31	
0,18	0,55	1,18	1,34	
0,22	0,57	1,18	1,35	
0,26	0,60	1,21	1,36	
0,30	0,62	1,22	1,38	
0,35	0,65	1,25	1,38	
0,40	0,67	1,28	1,39	
0,45	0,68	1,32	1,40	
1,03	1,03	1,05	1,01	Db 100% Yellow

Table 1-4

Db Undercolor		Db Overprint		
0,05	0,47	1,09	1,31	
0,09	0,49	1,11	1,33	
0,13	0,52	1,14	1,36	
0,17	0,55	1,17	1,36	
0,22	0,57	1,17	1,38	
0,26	0,60	1,20	1,38	
0,30	0,62	1,23	1,39	
0,34	0,64	1,24	1,40	
0,40	0,67	1,30	1,42	
0,46	0,68	1,33	1,43	
1,00	1,02	1,04	1,00	Db 100% Yellow

Density values of the individual samples

Table 1-5

Db Undercolor		Db Overprint		
0,05	0,47	1,08	1,30	
0,09	0,50	1,10	1,31	
0,13	0,52	1,12	1,33	
0,18	0,55	1,16	1,35	
0,21	0,57	1,16	1,35	
0,26	0,60	1,18	1,35	
0,29	0,62	1,21	1,35	
0,34	0,65	1,22	1,38	
0,39	0,66	1,26	1,38	
0,44	0,67	1,29	1,39	
1,01	1,01	1,03	0,99	Db 100% Yellow

Table 1-6

Db Undercolor		Db Overprint		
0,05	0,48	1,09	1,30	
0,09	0,50	1,09	1,30	
0,14	0,53	1,14	1,35	
0,18	0,56	1,17	1,36	
0,22	0,58	1,17	1,34	
0,26	0,60	1,18	1,35	
0,30	0,63	1,22	1,36	
0,34	0,65	1,23	1,38	
0,39	0,66	1,29	1,38	
0,45	0,68	1,30	1,39	
1,02	1,03	1,04	1,01	Db 100% Yellow

Density values of the individual samples

Table 1-7

Db Undercolor		Db Overprint		
0,05	0,47	1,11	1,33	
0,09	0,50	1,12	1,32	
0,13	0,52	1,15	1,34	
0,17	0,56	1,19	1,35	
0,22	0,58	1,18	1,37	
0,26	0,60	1,22	1,36	
0,29	0,63	1,24	1,38	
0,34	0,65	1,26	1,38	
0,39	0,67	1,30	1,39	
0,45	0,69	1,34	1,40	
1,03	1,04	1,05	1,01	Db 100% Yellow

Table 1-8

Db Undercolor		Db Overprint		
0,06	0,47	1,09	1,30	
0,10	0,50	1,09	1,30	
0,14	0,53	1,14	1,32	
0,17	0,56	1,16	1,33	
0,22	0,58	1,18	1,34	
0,26	0,61	1,18	1,34	
0,30	0,63	1,23	1,36	
0,34	0,65	1,25	1,37	
0,38	0,67	1,29	1,39	
0,45	0,68	1,33	1,39	
1,01	1,02	1,03	0,99	Db 100% Yellow

Density values of the individual samples

Table 1-9

Db Undercolor		Db Overprint		
0,05	0,48	1,09	1,31	
0,09	0,51	1,10	1,31	
0,13	0,53	1,13	1,32	
0,17	0,57	1,17	1,35	
0,22	0,59	1,18	1,37	
0,26	0,62	1,20	1,38	
0,30	0,64	1,23	1,38	
0,35	0,66	1,26	1,40	
0,39	0,67	1,27	1,40	
0,43	0,67	1,31	1,41	
1,02	1,02	1,05	1,00	Db 100% Yellow

Table 1-10

Db Undercolor		Db Overprint		
0,06	0,48	1,10	1,33	
0,10	0,51	1,11	1,33	
0,14	0,54	1,15	1,35	
0,18	0,57	1,18	1,38	
0,22	0,59	1,20	1,38	
0,26	0,62	1,22	1,38	
0,30	0,64	1,25	1,41	
0,35	0,66	1,27	1,43	
0,39	0,68	1,31	1,43	
0,44	0,68	1,34	1,43	
1,02	1,04	1,04	1,01	Db 100% Yellow

Table 2

Percent Ink Trapping of the Individual Samples

Percent Underneath Area Coverage	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
15%	102,97	103,00	101,98	104,00	104,04	102,97	104,95	104,04	104,00	102,97
30%	100,99	100,00	101,98	102,00	102,02	99,01	101,98	100,00	101,00	100,00
45%	99,01	98,00	98,02	101,00	100,00	99,01	100,99	101,01	100,00	100,00
60%	100,00	98,00	99,01	100,00	98,99	98,02	100,99	100,00	100,00	99,01
75%	97,03	96,00	95,05	95,00	95,96	94,06	95,05	96,97	96,00	97,03
90%	94,06	92,00	94,06	94,00	92,93	91,09	95,05	92,93	94,00	95,05
105%	91,09	91,00	91,09	93,00	92,93	91,09	94,06	93,94	93,00	94,06
120%	90,10	88,00	89,11	90,00	88,89	88,12	91,09	91,92	91,00	91,09
135%	90,10	88,00	87,13	90,00	87,88	89,11	90,10	91,92	88,00	91,09
150%	87,13	85,00	86,14	87,00	85,86	84,16	88,12	88,89	88,00	89,11
165%	81,19	82,00	83,17	84,00	83,84	81,19	85,15	83,84	83,00	84,16
180%	81,19	81,00	80,20	84,00	81,82	79,21	81,19	80,81	80,00	81,19
195%	79,21	80,00	79,21	84,00	81,82	81,19	81,19	79,80	79,00	80,20
210%	77,23	76,00	78,22	81,00	80,81	79,21	78,22	77,78	78,00	80,20
225%	76,24	75,00	77,23	81,00	78,79	75,25	78,22	76,77	78,00	78,22
240%	74,26	71,00	75,25	78,00	75,76	74,26	75,25	73,74	76,00	75,25
255%	73,27	71,00	75,25	77,00	73,74	72,28	74,26	73,74	74,00	76,24
270%	71,29	71,00	72,28	76,00	73,74	72,28	72,28	72,73	74,00	76,24
285%	70,30	71,00	71,29	75,00	72,73	71,29	71,29	72,73	73,00	74,26
300%	70,30	70,00	71,29	75,00	72,73	70,30	70,30	71,72	74,00	74,26

Figure 4

Plot of the relationship between percent underneath area coverage and ink trapping for each of the samples

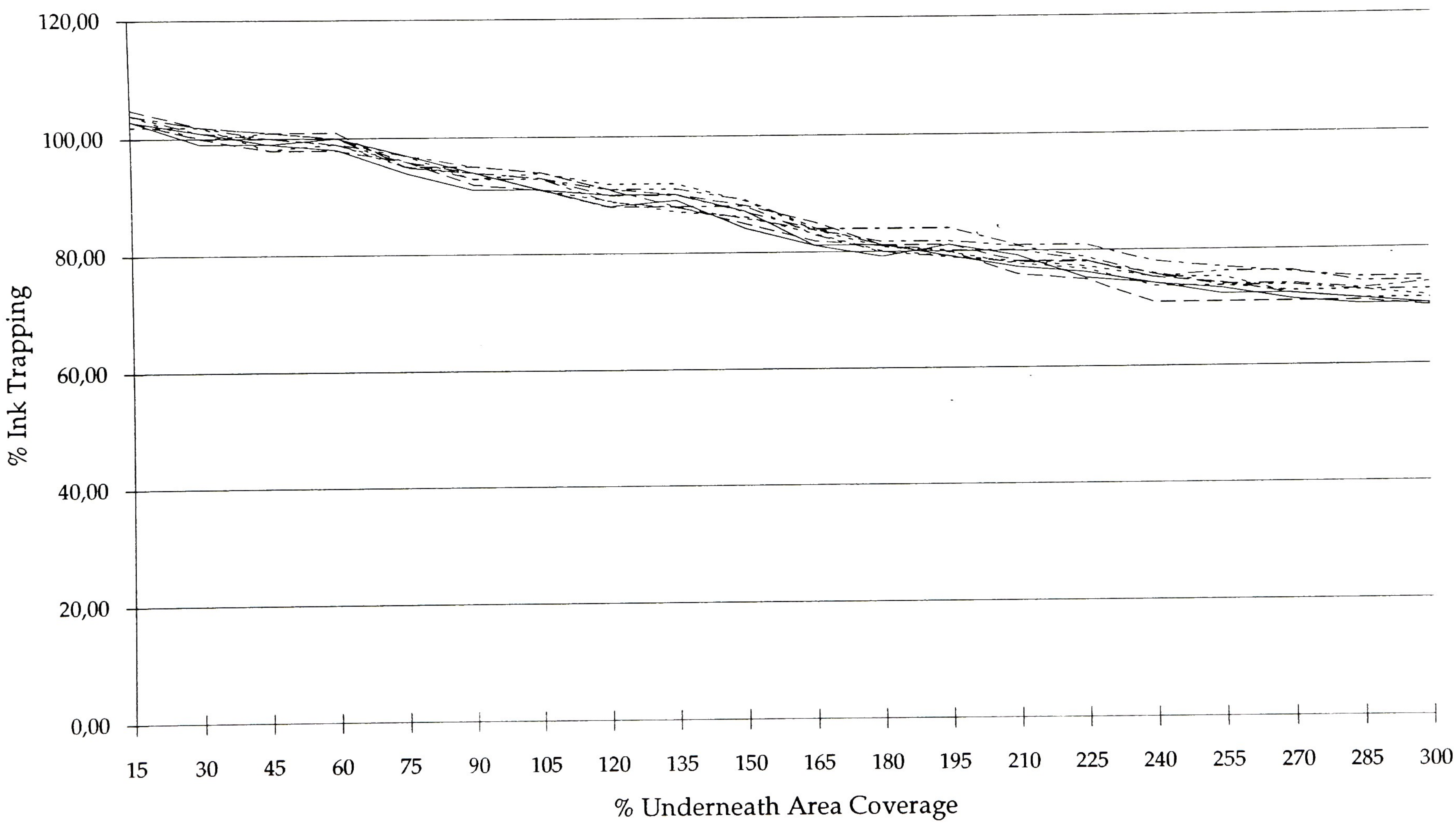


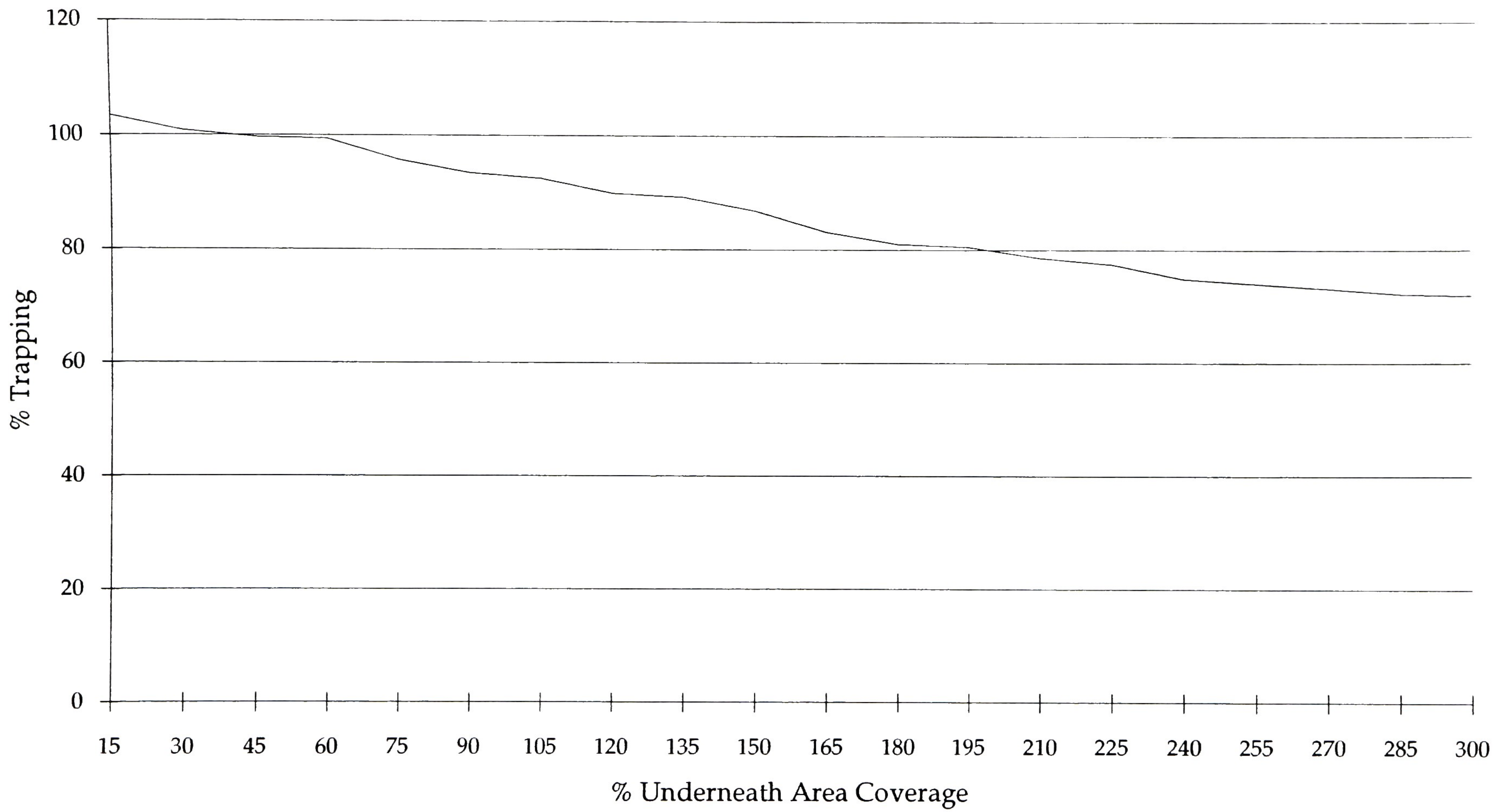
Table 3

Average Percent Ink Trapping

Percent Underneath Area Coverage	Average Percent Ink Trapping
15%	103,49
30%	100,9
45%	99,701
60%	99,402
75%	95,813
90%	93,519
105%	92,522
120%	89,93
135%	89,332
150%	86,939
165%	83,151
180%	81,057
195%	80,558
210%	78,664
225%	77,468
240%	74,875
255%	74,078
270%	73,18
285%	72,283
300%	71,984

Figure 5

Plot of the relationship between average ink trapping and percent underneath area coverage



Endnotes for Chapter 4

[16] Long, R. and Browne, R. *"Print Analysis and Colorimetry of North American Commercial Printing."* TAGA Proceedings 1988, p. 654

Conclusions

The objective of the investigation was to study the relationship between ink trapping and percentage underneath area coverage. Specifically, we were looking for the behavior of the ink trapping values of a solid ink film when printed over different combinations of percent area coverage formed by the first three down inks.

The investigation addressed percent area coverage from a trapping point of view. The color target was designed in such a way that it allowed us to collect all the necessary data to study that relationship. From the measurement of the target and from the analysis of the results, we can draw the following conclusions:

1) There is an inverse relationship between ink film trapping and percent underneath area coverage for the particular conditions of this investigation. Ink trapping theory tells us that an ink adheres better to the paper than it does over a wet ink. Following this statement, the relationship between percent ink trapping and percentage underneath area coverage should be a negative one. This means that the more area coverage underneath a solid the less ink trapping should occur. From the analysis of the plot of the experimental data we confirm such a relationship.

2) There is a linear relationship between ink trapping and percent underneath area coverage. Ink trapping falls at a constant rate as the percentage underneath area coverage increases. There is no percent underneath area coverage range at which ink trapping stays constant or point at which ink trapping begins to fall more rapidly than in another range.

Implications

Maximum area coverage can be specified on the basis of how low an ink trapping value a printer can live with. We observed that at 300% total area coverage, the ink trapping value was of 80%. At 400% maximum area coverage, that is four solid inks printed one on top of the other, the ink trapping value was of 72%. If the printer experiences that 72% ink trapping is a value that he can live with, then there is no problem in attempting 400% total area coverage in the color separation phase.

On the other hand, if the printer considers that 80% ink trapping is the minimum that he is willing to accept, then a 300% total area coverage limit is the recommendable practice.

From the linear relationship between ink film trapping and percent underneath area coverage we can imply that the more area coverage, the less ink trapping will be obtained. This has serious implications when printing more than four colors, when the total area coverage can go over 400%. New technologies are exploring the possibility of printing with seven process inks. From the study of the ink trapping theory and the results of this investigation, we anticipate ink trapping problems in these new technologies.

Recommendations for further study.

This study shows a clear trend in the relationship between ink trapping and percent underneath area coverage. This is an area with strong theoretical support but not much experimentation, I hope that this study will trigger other graphic arts professionals into investigating related issues. Some suggested areas for research could be:

1) Study of the relationship between ink trapping and percent underneath area coverage for different kinds of paper (coated, uncoated, newsprint.) and different kinds of presses (sheetfed, heat web, non-heat web.)

2) Study of the stability of the relationship between ink trapping and percent underneath area coverage throughout the press run.

3) Study of the relationship between ink trapping and percent underneath area coverage for two color and three color overprints and determination of its variation throughout the press run.

4) Study of the relationship between ink trapping and percent underneath area coverage by doing a quantitative measurement of ink trapping. This could be achieved by measuring the actual amount of ink that is transferred to the underneath area coverage using an scanning electron microscope.

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